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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02077826.2

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02077826.2
Demande no:

Anmeldetag:
Date of filing: 10.07.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Circuit arrangement

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

H05B33/00

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

Circuit arrangement

The invention relates to a circuit arrangement for supplying a LED array comprising

- input terminals for connection to a voltage supply source,
- output terminals for connection to the LED array,
- a DC-DC-converter coupled between the input terminals and the output terminals and equipped with
  - an inductive element L,
  - a unidirectional element,
  - a switching element coupled to the inductive element and the unidirectional element,
  - a control circuit coupled to a control electrode of the switching element for generating a high frequency control signal for rendering the switching element conductive and non-conductive at a high frequency to thereby operate the DC-DC-converter in the critical discontinuous mode and equipped with means I for controlling the current through the output terminals at a predetermined value.

The invention also relates to an Liquid crystal Display equipped with a backlight formed by a LED array.

A circuit arrangement as mentioned in the opening paragraph is well known. Operation in the critical discontinuous mode means that the current through the inductive element L equals zero at the beginning and at the end of each period of the control signal, while it differs from zero during each period of the control signal. This mode of operation ensures a high efficiency since power losses in the unidirectional element are prevented to a large extent. In the known converter the means I for controlling the current through the output terminals consist of a current control loop equipped with feedback. The actual value of the current is measured and compared with a desired value by means of a comparator that generates an error signal that in turn adjusts the control signal in such a way that the actual value of the current through the output terminals substantially equals the desired value. An advantage of such a control loop is that it allows a very accurate control of the value of the current. Disadvantages, however, are that the control loop is expensive since it comprises

many components and that the control loop is comparatively slow. Furthermore, in case the actual value of the current is measured by measuring the voltage across an ohmic resistor that is placed in series with the output terminals, the control loop also causes a substantial power dissipation.

The invention aims to provide a circuit arrangement comprising means for controlling the output current, wherein the disadvantages mentioned hereabove are absent.

A circuit arrangement as mentioned in the opening paragraph is therefor in accordance with the invention characterized in that the means I comprise means coupled to the input terminals and the output terminals for controlling the time lapse Ton, during which the switching element is maintained in a conductive state during each high frequency period of the control signal, proportional to a mathematical expression that is a function of Vin and Vout, wherein Vin is the voltage present between the input terminals and Vout is the voltage present between the output terminals.

The means I in a circuit arrangement according to the invention can be realized in a comparatively simple and inexpensive way. It has been found that the means I counteracts changes in the input or output voltage of the circuit arrangement relatively fast and controls the current through the output terminals at a substantially constant level. The means I in a circuit arrangement according to the invention also do not dissipate a substantial amount of power.

DC-DC-converters of different type can be used in a circuit arrangement according to the present invention. Good results have been obtained in case the DC-DC-converter is an up-converter and the means I comprise means for controlling Ton proportional to $Vout/Vin^2$. Similarly, the DC-DC-converter can be implemented as a down-converter while the means I comprise means for controlling Ton proportional to $Vout/((Vout-Vin)^2$. Good results have also been obtained in case the DC-DC-converter is a flyback-converter that comprises a transformer with a transformation ratio N and the means I comprise means for controlling Ton proportional to $(Vin + Vout/N)/Vin^2$.

Good results have been obtained for embodiments of a circuit arrangement according to the invention, wherein the means I comprise a current source that generates a current that is proportional to Vin^2. Such a current source can be realized in a simple and dependable way, in case the current source comprises a first voltage divider coupled to the input terminals, a first zener diode coupled to the first voltage divider and a switching element coupled to the first zener diode. In a preferred embodiment the current source

comprises a second zener diode. The second zener diode allows the means I to render Ton proportional to $1/Vin^2$ for two different values of the input voltage (e.g. 12 V and 24 V). In addition to the current source, the control circuit preferably comprises

- a capacitor coupled to the current source, and
- a comparator equipped with
  - a first comparator input terminal coupled to the capacitor,
  - a second comparator input terminal coupled to an output terminal of a second voltage divider coupled to the output terminals of the circuit arrangement, and
  - a comparator output terminal coupled to the control electrode of the switching element.

In case it is desirable to control the light output of the LED array operated by a circuit arrangement according to the invention, the control circuit is preferably equipped with means III for substantially square wave modulating the amplitude of the current through the output terminals. The means III switch the current through the LEDs off during part of each period of the modulation and on during the remaining part. By adjusting the time lapse in each period of the modulation during which the LEDs carry a current, the light output of the LEDs can be adjusted. It is observed that the means III can be incorporated in the control circuit since the feed forward control of Iout by the means I in a circuit arrangement according to the invention is comparatively fast. In most known circuit arrangements equipped with a current control loop comprising feedback, the means III cannot be comprised in the control circuit since the control loop is too slow. In fact the means for modulating have to be realized in the form of a "chopper" that usually comprises a (semiconductor) switch and drive circuitry for driving the switch. The switch realizes the modulation by "chopping" the output current of the circuit arrangement. Such a chopper is comparatively expensive, generates interference and decreases the efficiency of the circuit arrangement for instance by hard switching. Furthermore, it is often necessary to take care of for instance interference shielding and dampening, increasing the costs and the complexity of the circuit arrangement even further. The fast control of the output current realized by the means I comprised in a circuit arrangement according to the present invention allows the modulation of the output current to be effected by a means III that is part of the control circuit. As a consequence the means III are comparatively cheap, do not cause interference and do not lower the efficiency of the circuit arrangement.

It has been found that a circuit arrangement according to the invention is particularly suitable for use in an LCD equipped with a backlight formed by a LED array.

Embodiments of the invention will be described making reference to a drawing. In the drawing

Fig. 1 shows an embodiment of a circuit arrangement according to the invention with a LED array connected to it and comprising a DC-DC-converter of the up-converter type, and

Fig. 2 shows part of the embodiment shown in Fig. 1 in more detail.

In Fig. 1, K1 and K2 are input terminals for connection to a voltage supply source. Input terminals K1 and K2 are connected by means of a series arrangement of inductive element L and switching element Q1. Switching element Q1 is shunted by a series arrangement of ohmic resistor R1 and capacitor C1 and by a series arrangement of diode D1 and capacitor C2. In this embodiment diode D1 forms a unidirectional element. Respective sides of capacitor C2 are connected with output terminal K3 and output terminal K4. A LED array LEDA is connected between output terminals K3 and K4. A control electrode of switching element Q1 is connected to an output terminal of circuit part I via a switching element Q2. Circuit part I forms means I for controlling the current through output terminals K3 and K4 at a predetermined value. Respective input terminals of circuit part I are connected to input terminal K1, output terminal K3 and an output terminal of a circuit part CC. Circuit part CC is a circuit part for controlling when the switching element Q1 needs to be rendered conductive. Respective input terminals of the circuit part CC are connected to input terminal K1 and a common terminal of inductive element L and switching element Q1. A control electrode of switching element Q2 is coupled to an output terminal of circuit part IIIa. In Fig. 1 this is indicated by means of a dotted line. An input terminal of circuit part IIIa is coupled to a light sensor LS. The light sensor LS, the circuit part IIIa and the switching element Q2 together form means III for substantially square wave modulating the amplitude of the current through the output terminals. Inductive element L, switching element Q1, capacitors C1 and C2, ohmic resistor R1, diode D1, light sensor LS, circuit parts IIIa, CC and I and switching element Q2 together form a DC-DC-converter of the up-converter type. The light sensor LS, the circuit parts IIIa, CC, I and the switching element Q2 together form a control circuit for generating a high frequency control signal for rendering the switching element Q1 conductive and non-conductive at a high frequency to thereby operate the DC-DC-converter in the critical discontinuous mode.

The operation of the circuit arrangement shown in Fig. 1 is as follows.

When input terminals K1 and K2 are connected to a supply voltage source and circuit part IIIa controls switching element Q2 in a conductive state, the control circuit renders the switching element Q1 conductive and non-conductive at a high frequency in such a way that the DC-DC-converter is operated in the critical discontinuous mode. As pointed out hereabove this means that the amplitude of the current through the inductive element is substantially zero at the beginning and at the end of each period of the control signal. As a result, a DC current flows through the output terminals K3 and K4 and the LED array LEDA emits light.

The control circuit controls the switching in the following way. Because of the presence of capacitor C1 (and the parasitic capacitor that is part of switching element Q1), the direction of the current through the inductive element L changes polarity for a very short time lapse at the end of each period of the control signal. As consequence a current with a very small amplitude flows from the capacitor C1 in the direction of the input terminal K1. This causes the common terminal of switching element Q1 and the inductive element L to be at a higher potential than input terminal K1. Circuit part CC detects this situation and activates circuit part I that renders switching element Q1 conductive and maintains switching element Q1 conductive during a time lapse Ton that is proportional to $Vout/Vin^2$, wherein Vin is the voltage that is present between the input terminals and Vout is the voltage between the output terminals. During Ton the current through inductive element L increases linearly to a value Ipeak. For the value of Ipeak the following equation is valid:

$$Ipeak = Vin. Ton/Lo,$$

wherein Lo is the inductivity of inductive element L.

At the end of the time lapse Ton the switching element Q1 is rendered non-conductive by circuit part I. During the remaining part of the period of the control signal the amplitude of the current through inductive element L decreases linearly to substantially zero. As a consequence the shape of the current through inductive element L is triangular and the average value of the current through inductive element L in each period of the control signal therefore equals Ipeak/2. It follows that for the power Pin that is consumed by the DC-DC-converter the following equation holds:

$$Pin = Vin . Ipeak/2.$$

When it is assumed that the voltage conversion by the DC-DC-converter is taking place without losses, the power supplied by the DC-DC-converter (Vout . Iout) to the LED array equals the power consumed by the DC-DC-converter:

$$Vin \cdot Ipeak/2 = Vout \cdot Iout,$$

wherein Iout is the current flowing through the output terminals K3 and K4.

From the above equations the next equation can easily be derived:

$$Ton = Iout \cdot 2 \cdot Lo \cdot Vout/Vin^2.$$

From this latter equation it can be seen that the current Iout can be maintained at a contant value, in case the time lapse Ton is controlled at a value that is proportional to $Vout/Vin^2$. As a consequence the output current Iout of the circuit arrangement shown in Fig. 1 remains substantially unchanged, when the input voltage Vin or the output voltage Vout changes.

During operation switching element Q2 is switched on and off at a much lower frequency than the frequency of the control signal that controls switching element Q1. During the part of the modulation period in which switching element Q2 is non-conductive the amplitude of the current Iout through the output terminals is zero. As a result, the amplitude of the current Iout through the output terminals is substantially square wave modulated. The light output of the LED array is monitored by the light sensor LS and a signal representing the average value of that light output is generated by circuit part IIIa. In circuit part IIIa this value is compared with a reference signal that is also generated by circuit part IIIa and represents the desired average value of the light output. The duty cycle of the signal controlling the conductive state of switching element Q2, or in other words the duty cycle of the modulation of the output current amplitude, is adjusted in accordance with the outcome of the comparison. As a result, the average value of the light output is controlled at a substantially constant level. It is noted that when switching element Q2 is rendered conductive (in each period of the modulation), the feed forward control of the output current effected by circuit part I is fast enough to make sure that the amplitude of Iout increases from substantially zero to a constant value in a comparatively short time. Unlike a much slower control loop incorporating current feedback, it is this fast control that allows the means III for

modulating the amplitude of Iout to be part of the control circuit so that a "chopper" causing interference and decreased efficiency can be dispensed with.

Fig. 2 shows circuit part I of the embodiment shown in Fig. 1 in more detail. In Fig. 2, K5 is a terminal that is connected to input terminal K1 and K6 is a terminal that is connected to input terminal K2, so that during operation the voltage Vin is present between terminals K5 and K6. Terminals K5 and K6 are connected by means of a series arrangement of ohmic resistor R1 and R3 and by means of a series arrangement of ohmic resistor R5, zener diode D3, transistor Q3 and capacitor C3. Ohmic resistor R3 is shunted by zener diode D2. A common terminal of ohmic resistor R3 and zener diode D2 is connected to a basis electrode of transistor Q3. Terminal K5 is connected to an emitter electrode of transistor Q3 by means of ohmic resistor R2. Capacitor C3 is shunted by a switching element Q4. A control electrode of switching element Q4 is connected to the output terminal of circuit part CC. Ohmic resistors R1, R2, R3 and R5, zener diodes D2 and D3 and transistor Q3 are so dimensioned that together they form a current source that is dimensioned to supply a current that is proportional to Vin^2. Terminal K8 is connected to output terminal K3. Terminal K8 is also connected to terminal K6 by means of a series arrangement of ohmic resistors R7 and R10. During operation the voltage Vout is present across this series arrangement. A common terminal of ohmic resistor R7 and ohmic resistor R10 is connected to a first input terminal of comparator COMP. A common terminal of transistor Q3 and capacitor C3 is connected to a second input terminal of comparator COMP. K7 is a comparator output terminal that is coupled to the control electrode of switching element Q1.

The operation of the circuit part I shown in Fig. 2 is as follows.

When the circuit part CC detects that the switching element Q1 needs to become conductive, the voltage at its output terminal changes from low to high and switching element Q4 is rendered conductive so that capacitor C3 is discharged. As a result the voltage present at the second input terminal of the comparator COMP becomes lower than the voltage present at the first input terminal of the comparator, so that the voltage present at the comparator output terminal K7 becomes high and switching element Q1 is rendered conductive. As soon as capacitor C3 is discharged switching element Q4 is rendered non-conductive again and the current source supplying a current that is proportional to Vin^2 charges capacitor C3. As long as the voltage over capacitor C3 is lower than the voltage at the first input terminal of the comparator COMP, the voltage at the comparator output terminal is high and switching element Q1 is maintained in a conductive state. The voltage at the output comparator terminal becomes low and therefor the switching element Q1 becomes

non-conductive, when the voltage across capacitor C3 becomes equal to the voltage at the first input terminal of the comparator COMP. Since the current charging capacitor C3 is proportional to Vin^2 and the voltage at the first input terminal is proportional to Vout, it follows that Ton is proportional to $Vout/Vin^2$. The current source is designed in such a way that is suitable for use with two different values of Vin, such as 12 V and 24 V. At the lowest value of the two different values of Vin, only zener diode D2 and not zener diode D3 is conductive. As a consequence the current supplied by the current source is the current through ohmic resistor R2. At the highest of the two different values of Vin, both zener diodes are conducting and the current supplied by the current source is the sum of the currents through ohmic resistors R2 and R5.

It is noteworthy to observe that the current source in circuit part I in Fig.2 is so designed that the current it supplies is proportional to Vin^2 only to a good approximation and not exactly. Furthermore, Vin is often supplied by a battery and therefor will only vary over a limited range. As a consequence it is only necessary for the current source to supply a current that is approximately proportional to Vin^2, for values of Vin that differ not too much (for instance only 10% or 20% at most) from the average value of Vin. In case for instance the current source is designed for an average value of Vin that equals 12 V, it is in most practical cases completely satisfactory when the current source supplies a current that is approximately proportional to Vin^2 for values of Vin within the range $10.8V < Vin < 13.2V$. Similarly, in case the current source is designed for two different average values of Vin such as 12V and 24 V, satisfactory results are obtained when the current source only supplies a current that is approximately proportional to Vin^2, for values of Vin for instance within the range $10.8V < Vin < 13.2V$ and for values of Vin for instance within the range $21.6V < Vin < 26.4V$.

In a practical embodiment of the circuitry shown in Fig. 1 and Fig. 2 it was found that a variation by 10% of Vin caused the output current Iout to change by less than 3%. Similarly a variation by 20% of Vin caused the output current Iout to change by less than 5%. In case the means I would be absent, or in other words in case the Ton of switching element Q1 would remain unchanged, a 10 % variation in the input voltage Vin would lead to a 20% change in the output current, while a 20% variation in the input voltage Vin would lead to a 40% change in the output current Iout.

CLAIMS:

1. A circuit arrangement for supplying a LED array comprising

- input terminals for connection to a voltage supply source,
- output terminals for connection to the LED array,
- a DC-DC-converter coupled between the input terminals and the output terminals and equipped with
  - an inductive element L,
  - a unidirectional element,
  - a switching element coupled to the inductive element and the unidirectional element,
  - a control circuit coupled to a control electrode of the switching element for generating a high frequency control signal for rendering the switching element conductive and non-conductive at a high frequency to thereby operate the DC-DC-converter in the critical discontinuous mode and equipped with means I for controlling the current through the output terminals at a predetermined value,

characterized in that the means I comprise means coupled to the input terminals and the output terminals for controlling the time lapse Ton, during which the switching element is maintained in a conductive state during each high frequency period of the control signal, proportional to a mathematical expression that is a function of Vin and Vout, wherein Vin is the voltage present between the input terminals and Vout is the voltage present between the output terminals.

2. A circuit arrangement as claimed in claim 1, wherein the DC-DC-converter is an up-converter and the means I comprise means for controlling Ton proportional to $Vout/Vin^2$.

3. A circuit arrangement as claimed in claim 1, wherein the DC-DC-converter is a down-converter and the means I comprise means for controlling Ton proportional to $Vout/((Vout-Vin)^2$.

4. A circuit arrangement as claimed in claim 1, wherein the DC-DC-converter is a flyback-converter comprising a transformer with a transformation ratio N and the means I comprise means for controlling Ton proportional to $(Vin + Vout/N)/Vin^2$.

5. A circuit arrangement as claimed in claim 2 or 4, wherein the means I comprise a current source that generates a current that is proportional to Vin^2.

6. A circuit arrangement as claimed in claim 5, wherein the current source comprises a first voltage divider coupled to the input terminals, a first zener diode coupled to the first voltage divider and a switching element coupled to the first zener diode.

7. A circuit arrangement as claimed in claim 6, wherein the current source comprises a second zener diode.

8. A circuit arrangement as claimed in claim 5, 6 or 7, wherein the means I further comprises

- a capacitor coupled to the current source, and
- a comparator equipped with
  - a first comparator input terminal coupled to the capacitor,
  - a second comparator input terminal coupled to an output terminal of a second voltage divider coupled to the output terminals of the circuit arrangement, and
  - a comparator output terminal coupled to the control electrode of the switching element.

9. A circuit arrangement as claimed one or more of the previous claims, wherein the control circuit is equipped with means III for substantially square wave modulating the amplitude of the current through the output terminals.

10. A Liquid Crystal Display unit equipped with a backlight formed by a LED array and with a circuit arrangement as claimed in one or more of the previous claims.

ABSTRACT:

In an up-converter feed forward control of the output current is effected by rendering the conduction time of the switching element proportional to $Vout/Vin^2$. This control is fast and avoids interference and loss of efficiency.

Fig. 1

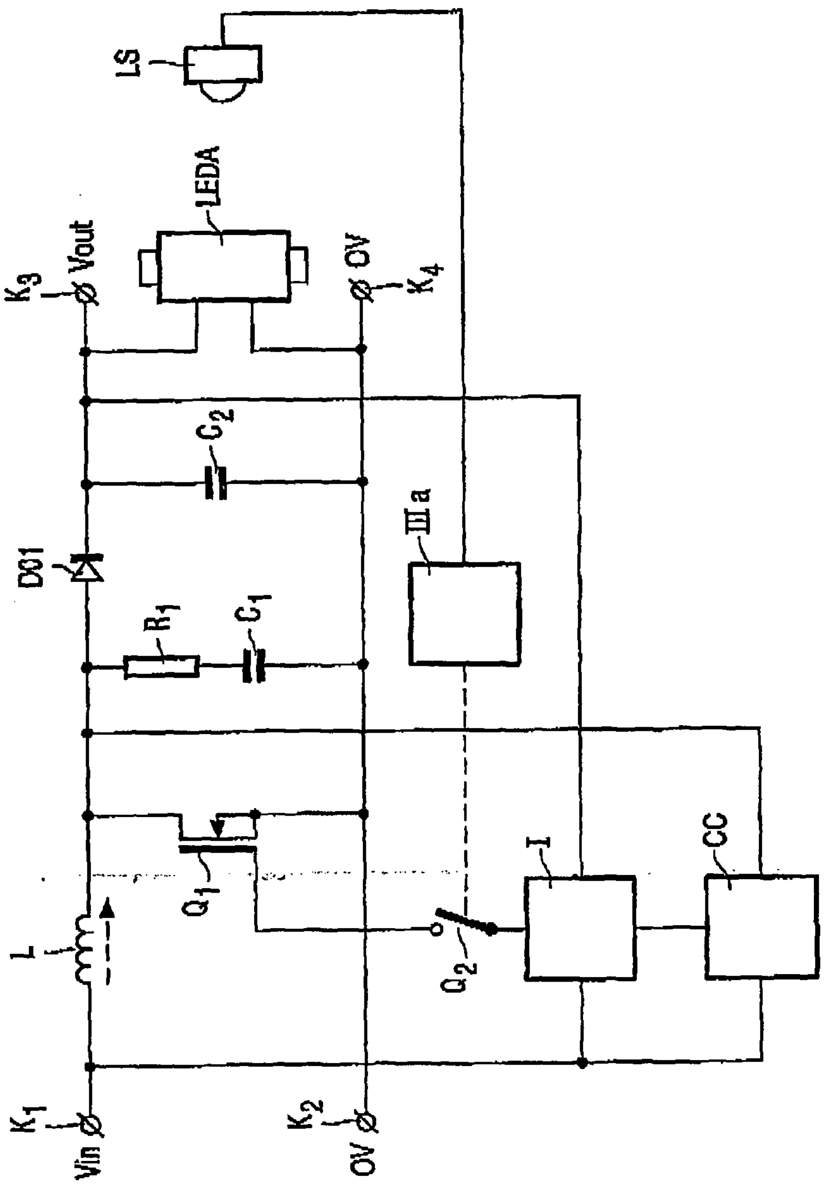

FIG. 1

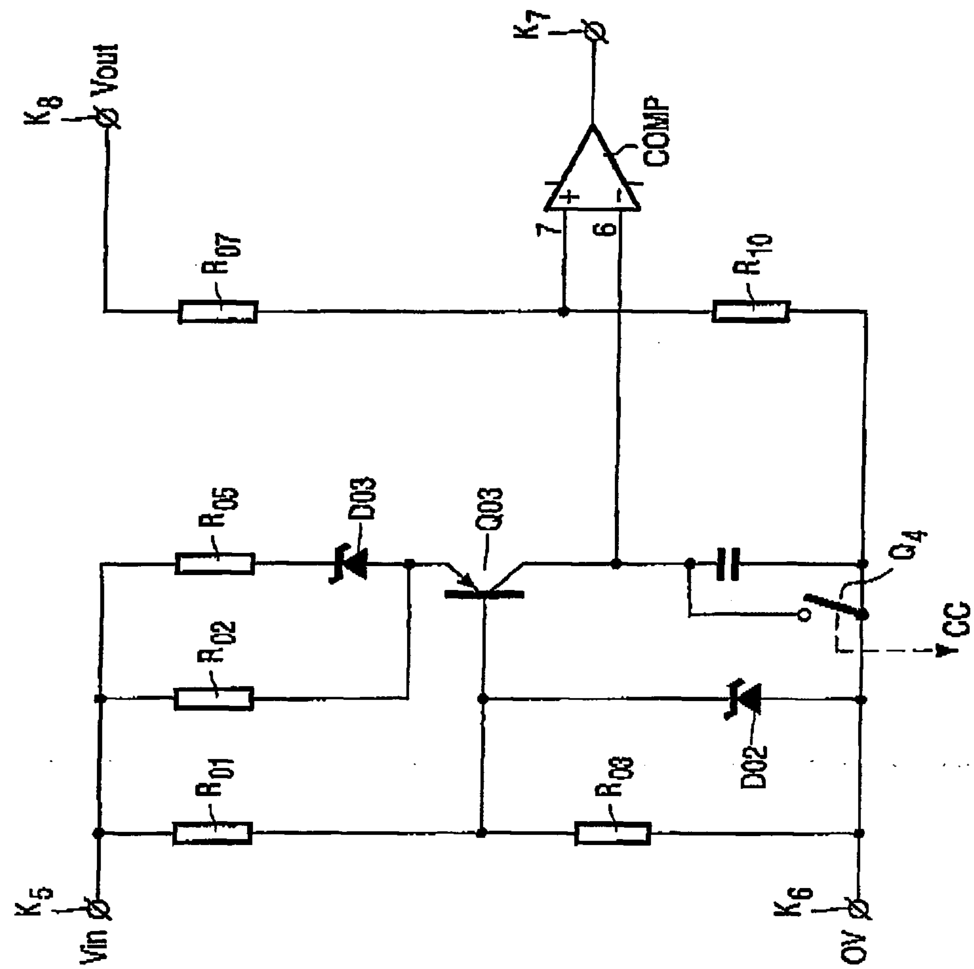
K8
Vout
K7
COMP
7
6
R07
R10
R05
D03
Q03
R02
R01
R03
D02
Q4
CC
K5
Vin
K6
OV

FIG. 2